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LEAK SEARCH RESULTS FOR 1990 PNGS PRESSURE RELIEF DUCT PRESSURE TESTS

Report No. 90-216-K

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ABSTRACT

At Ontario Hydro's nuclear generating stations, the containment volume is maintained at negative pressure to minimize radionuclide dispersion. At Pickering NGS, the various components of the containment volume are periodically pressurized to evaluate their integrity and to test for leakage. The tracer gas technique was used during the May, 1990 Vacuum Building Outage at Pickering NGS to identify leakage locations during the Pressure Relief Duct (PRD) "As Found" and "As Left" containment pressure tests. A 2.65% v/v ethylene in nitrogen mixture was injected into the PRD during each test. Over 250 samples of air were collected and analyzed for evidence of tracer gas at pressures of 14 and 41 kPag. During the "As Found" pressure test, leakage was detected from the majority of the Pressure Relief Duct (PRD) expansion joint seals, five of the Pressure Relief Valves (PRV) and three of the Reactor Building (RB) -PRD bulkheads. For the "As Left" PRD pressure test, leakage was detected from a number of the PRD expansion joint seals, from one of the RB - PRD bulkheads and through five of the PRV's. However, the combined leakage rate of the "As Left" PRD and interface components was less than the Ontario Hydro operational target of 1%/hour and the AECB licencing limit (safety analysis value) of 2%/hour for the PRD. The tracer gas technique provided PNGS Operations with valuable information as to which of the 8 isolation bulkheads and 12 PRV's leaked and an qualitative estimate of leak rate.

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EXECUTIVE SUMMARY

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In CANDU type nuclear plants, a physical containment barrier and a requirement that containment be maintained at negative pressure, minimize the potential release of radionuclides. Periodic design pressure tests are required by the AECB to demonstrate the integrity (ie. that the AECB licensing limit for air leakage from the PRD is less than 2% per hour of the contained mass at design pressure) of the various containment components. During the May 1990 Vacuum Building Outage at Pickering NGS, "As Found" and "As Left" pressure tests of the Pressure Relief Duct (PRD) were conducted in accordance with AECB requirements. The tracer gas leak search technique was conducted concurrently to search for and to identify leakage locations and confirm isolation at test boundary.

In the present study a 2.65% v/v ethylene in nitrogen tracer was injected into the PRD to achieve a concentration of approximately 100 ppm ethylene at a PRD pressure of about 14 kPag for each pressure test. Over 250 air samples were collected and analyzed for evidence of ethylene at about 14 and 41 kPag during the two PRD pressure tests. For the "As Found" pressure test, leakage was detected from the majority of the PRD expansion joint seals, five of the Pressure Relief Valves (PRV), and three of the PRD-Reactor Building (RB) bulkheads. For the "As Left" pressure test, leakage was detected from a number of the PRD expansion joint seals, five of the PRV's and one of the PRD-RB bulkheads. The leakage rate as determined by Nuclear Engineering Department (NED) personnel at 13.8 kPag, for the "As Found" pressure test, was 2.6% per hour

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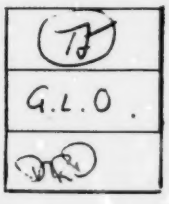
equivalent laminar leakage. A leakage rate at 41.4 kPag could not be determined as a PRD expansion joint seal ruptured at about 23 kPag while pressurizing to 41.4 kPag. After the seal replacement program and other repairs, the air leakage rate measured by NED personnel during the "As Left" pressure test was 0.92% at 13.8 kPag and 0.95% at 41.4 kPag. The leakage was estimated to be laminar in nature (ie, no significant holes).



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1 0 INTRODUCTION

At Pickering NGS, the containment boundary is composed of a number of components including the reactor buildings (RB), the pressure relief duct (PRD) and the vacuum building (VB), which together are used to minimize the potential release of radionuclides. Periodic tests are required by the Atomic Energy Control Board (AECB) to demonstrate the integrity of each containment boundary component. The PNGS station operational target for air leakage from the PRD is 1% per hour of the contained volume at design pressure (eg. 41.4 kPag for the PRD). The AECB licensing limit (safety analysis value) for the PRD is 2% per hour at design pressure.

As part of the May 1990 Pickering NGS station and vacuum building outage (VBOT), two positive pressure tests of the PRD were required/1/. The purpose of the first test was to measure the leakage rate of the PRD in the "As Found" condition (ie. before replacement of the joint seals and other repairs). This was to confirm that the PRD has been sufficiently leak tight since commissioning. The first pressure test was also to be used to identify any significant leakage areas and solve any problems which could arise regarding test boundary isolations (ie. PRD-Reactor Building (RB) bulkheads). If repairs or corrections were needed, then they could be done in the intervening time between the pressure tests.

Leak searching of the PRD was requested by PNGS Operations and recommended by Nuclear Engineering Department (NED)/2/ to complement the leakage rate measurements and to locate significant leak sites. Prior to the outage, it was recommended that tracer gas be used to detect and identify leakage from PRD isolations such as any of the eight reactor building (RB) bulkheads, the twelve pressure relief valves (PRV) and the fifteen PRD expansion joint (EJ) seals.

The tracer gas leak search was conducted at the locations listed in Table A1 and shown in Figure 1.

The "As Left" positive pressure test of the PRD structure was required to confirm the integrity and leak tightness at design pressure of (a) the PRD following new joint seal installation, (b) the replacement of boundary components associated with the pressure relief valves, and (c) any other structural repairs before PNGS was allowed to return to service. The Pickering NGS operating target for maximum air leakage from the PRD volume (31,000 m^3) is 1% per hour. The PRD had not been tested at positive pressure since commissioning. The proposed pressure tests would be the first of the entire length of the PRD structure.

The ethylene tracer gas leak search technique has been successfully demonstrated in a number of earlier studies at Bruce NGS 'A' and 'B'/3-5/. The traditional leak search technique, the application of soap solution around penetrations of the containment boundary, continues to be used. However, the technique has proven to be time- and labour-intensive while providing little useful information not provided by tracer gas. The soap solution method was found to be limited to suspected leak sites that are accessible. The tracer gas technique, on the other hand, was useful in detecting unsuspected leaks, required less exposure time when leak searching in radiation fields and could be used easily in relatively inaccessible areas.

Tracer gas leak searches of the PNGS PRD containment boundary were conducted at containment pressures of about 14 kPag during the "As Found" and at containment pressures of approximately 14 and 41 kPag during the "As Left" pressure tests of the May 1990 VBOT.

1.1 STRATEGY

Tracer gas injection into the PRD containment volume for the "As Found" and "As Left" pressure tests was to occur during the pressurization period to 13.8 kPag (2 psig). After stabilization at 13.8 kPag for about 15 min, air samples were to be collected at selected sites using Tedlar plastic bags. These samples were to be taken close to known containment penetrations which are inaccessible by soap spray leak search. All of the sites that were to be sampled during the tracer gas survey of the PRD penetrations are listed in Table A1 of Appendix A. After the air samples were analyzed by sensitive gas chromatography and evaluated, soap spray crews were dispatched to the areas where significant leaks had been identified by the air samples in order to locate the specific leak source.

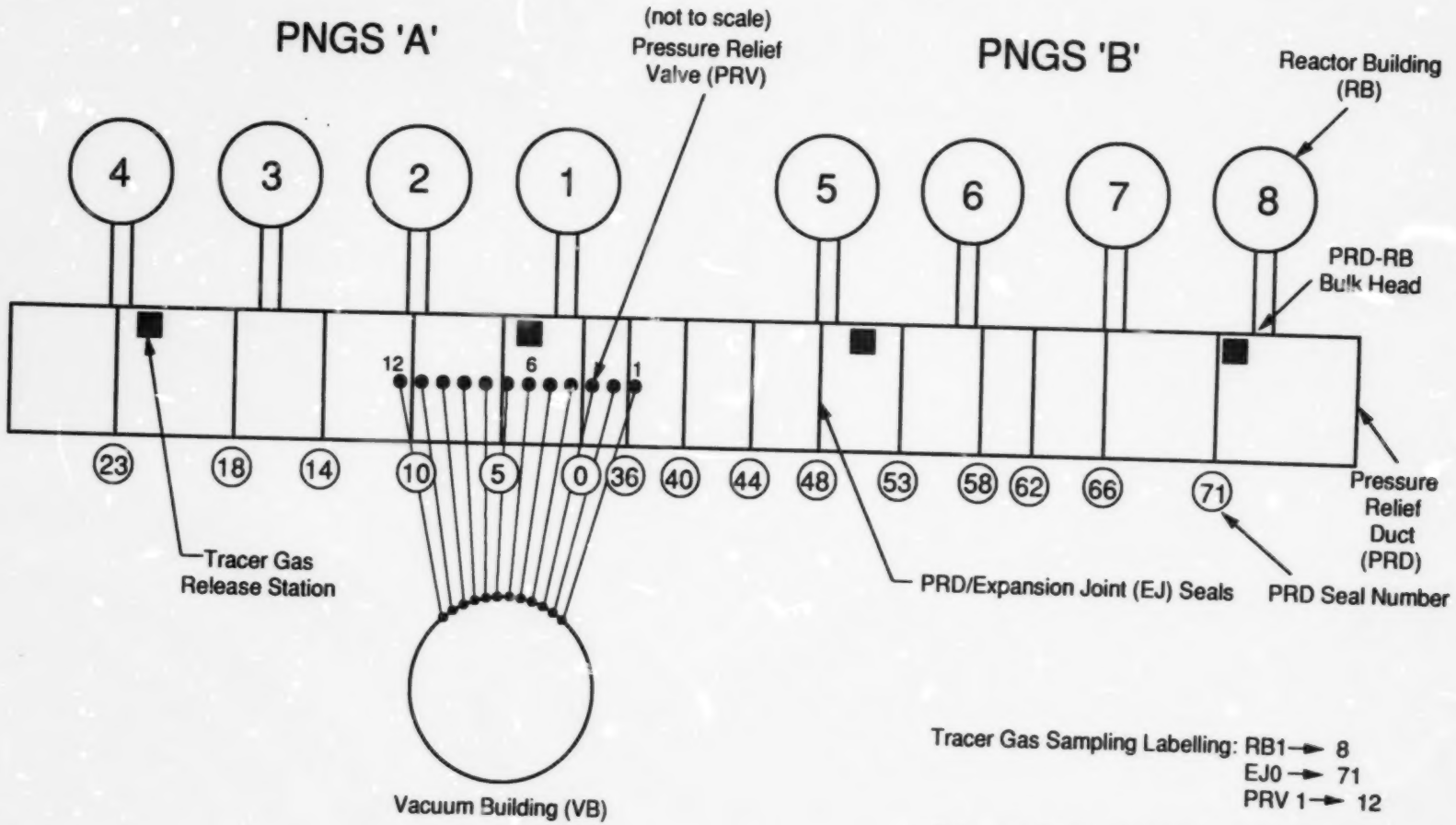

FIGURE 1

SCHEMATIC REPRESENTATION OF PICKERING NGS CONTAINMENT

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2.0 METHOD DETAILS

Ethylene was used as a tracer because of its ease of detection and handling and because it does not generate toxic or corrosive decomposition products/3/.

2.1 Tracer Gas Release System

The PRD internal dimensions are as follows:

height 7.62 m x width 6.10 m x length 661.5 m

giving an estimated internal volume of 30,700 m^3 for the PRD. Some additional volume was contributed by the eight transition ducts.

The pressurization air was injected into the PRD at a single location. To facilitate tracer gas mixing, four custom made 6-cylinder high pressure stainless steel manifolds (qualified for high pressure work/6/) were equally spaced along the PRD as shown in Figure 1. A tracer gas release system is shown schematically in Figure 2. The normally-closed stainless steel ASCO (Model 8223A) solenoid was used as the final isolation prior to release of the tracer gas.

The tracer gas was released into the PRD when the deactivated breaker of the circuit into which the ASCO solenoid was plugged, was manually activated. The tracer gas exited the cylinders through the stainless steel manifold, the two-stage regulator (Canadian Liquid Air Model 2504-350, with the outlet stage set to 100 psi (689.5 kPag)), the regulator shutoff valve, the activated two-way ASCO solenoid and the copper diffuser out into the PRD. Mixing of the tracer gas with the PRD volume air was assisted by portable fans, normal gas diffusion processes and by the turbulence created during injection of the pressurization air.

Twenty-four cylinders of 26.5 mL/L (2.65% v/v, whereas the lower explosive limit (LEL) of ethylene is 31mL/L (3.1% v/v) in air) ethylene in nitrogen (approximately 141,400 litres) were injected via manifold into the PRD during the "As Found" and "As Left" pressure tests.

2.2 Tracer Gas Sample Collection

Tedlar (Dupont) polyvinyl fluoride sample bags, each connected to a DC powered (1.5V or 3.0V) variable resistor throttled and switch operated pump, were used for air sampling. Each motor was activated manually and left to run until the sample bag was

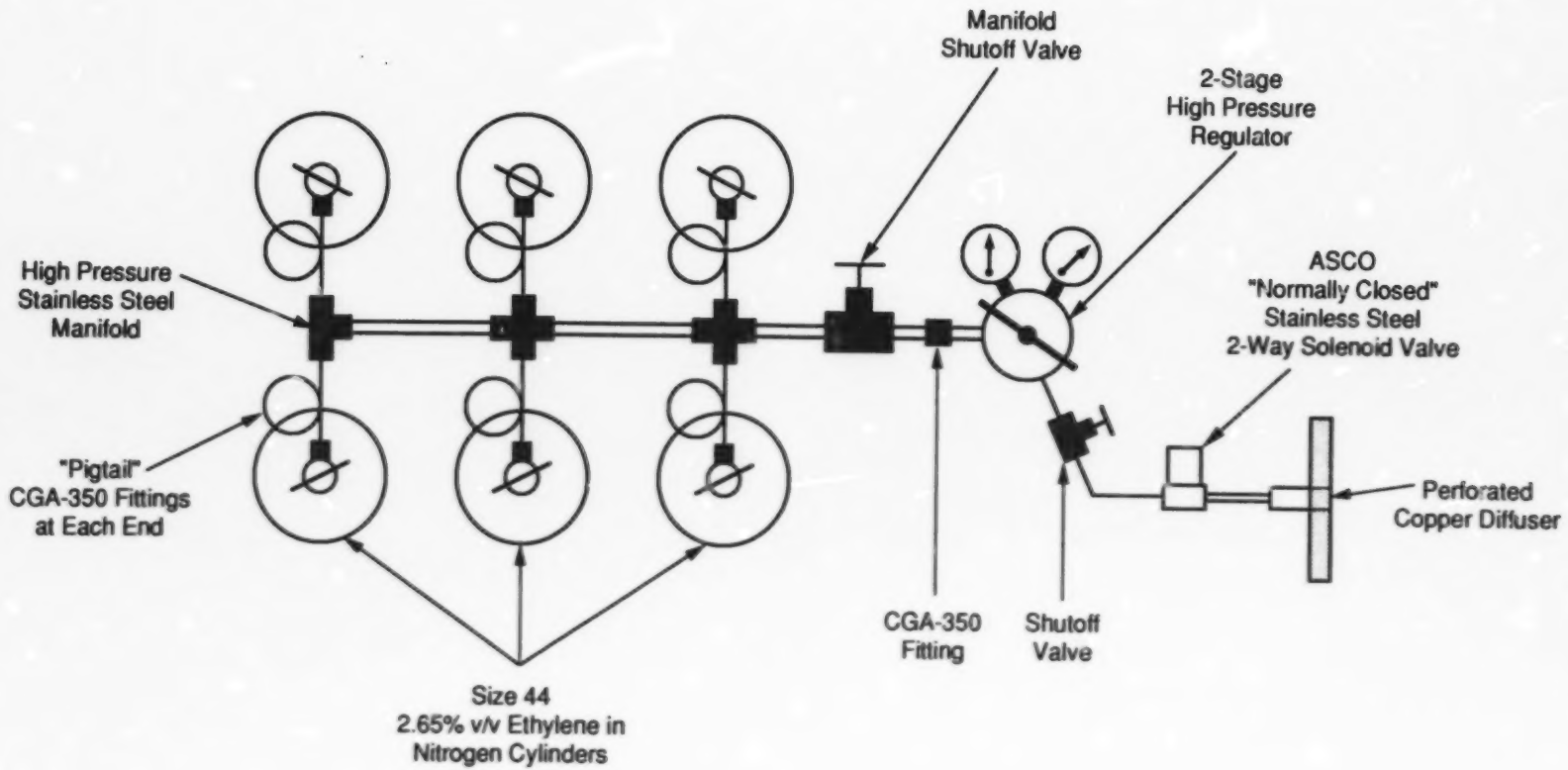

FIGURE 2

SCHEMATIC REPRESENTATION OF TRACER GAS RELEASE SYSTEM USED DURING 1990 PNGS OUTAGE PRD PRESSURE TESTS

approximately 3/4 full (about 2 to 5 min). Each bag was sealed mechanically with a Dura-clamp and returned for analysis to the Mobile Research Laboratory (MRL) located outside, southwest of the vacuum building.

2.3 Tracer Gas Sample Analysis

Two Photovac gas chromatographs (Models 10S50 and 10S30) equipped with photoionization detectors (PID) were used to analyze the air samples. The Photovac Model 10S50 had a built-in integrator whereas the Model 10S30 required an external integrator. The signal from the Model 10S30 detector was recorded on a Hewlett-Packard Model 3396A integrator.

The carrier gas was ultrapure air (Matheson) and was passed through a hydrocarbon scrubber prior to entering each gas chromatograph. The carrier gas flowrate for each gas chromatograph was about 10 mL/min. The ethylene detection limit was about 10 ppb (10 nL/L) for each instrument. The column used in each gas chromatograph was a 2.4 m x 0.318 cm OD Teflon tubing packed with 1.5% XE-60/1% H_3PO_4 on Carbopack B, 60/80 mesh. The injection volume was about 1 mL.

2.4 Gas Chromatograph Calibration

Two primary standard calibration gases of ethylene in ultrapure air (1.0 ppm and 100 ppm) were purchased from Matheson with each having a quoted concentration tolerance of $\pm$1%. Additional concentrations were generated using a dynamic dilution system described in an earlier report/7/. The calibration gas samples were blown into Tedlar bags and the concentrations determined in the same manner as for the field samples. The accuracy of the calibration concentrations thus generated was about $\pm$2%.

3.0 RESULTS AND DISCUSSION

The pressure versus time profile for the "As Found" positive pressure test measured by Nuclear Engineering Department (NED) is shown in Figure 3. The "As Found" PRD pressurization was begun at approximately 05:05 on May 7, 1990. The tracer gas injection was begun at about 05:30 (5 kPag) to ensure no large openings were present. The tracer gas concentration was projected to be about 100 ppm (100 µL/L) at a PRD containment pressure of 13.8 kPag.

The pressure versus time profile for the "As Left" positive pressure test is shown in Figure 4. The "As Left" PRD pressurization to 14 kPag was begun at 22:40 on May 22, 1990. The

FIGURE 3

1990 PNGS 'AS-FOUND' PRD PRESSURE TEST
PRD PRESSURE vs TIME

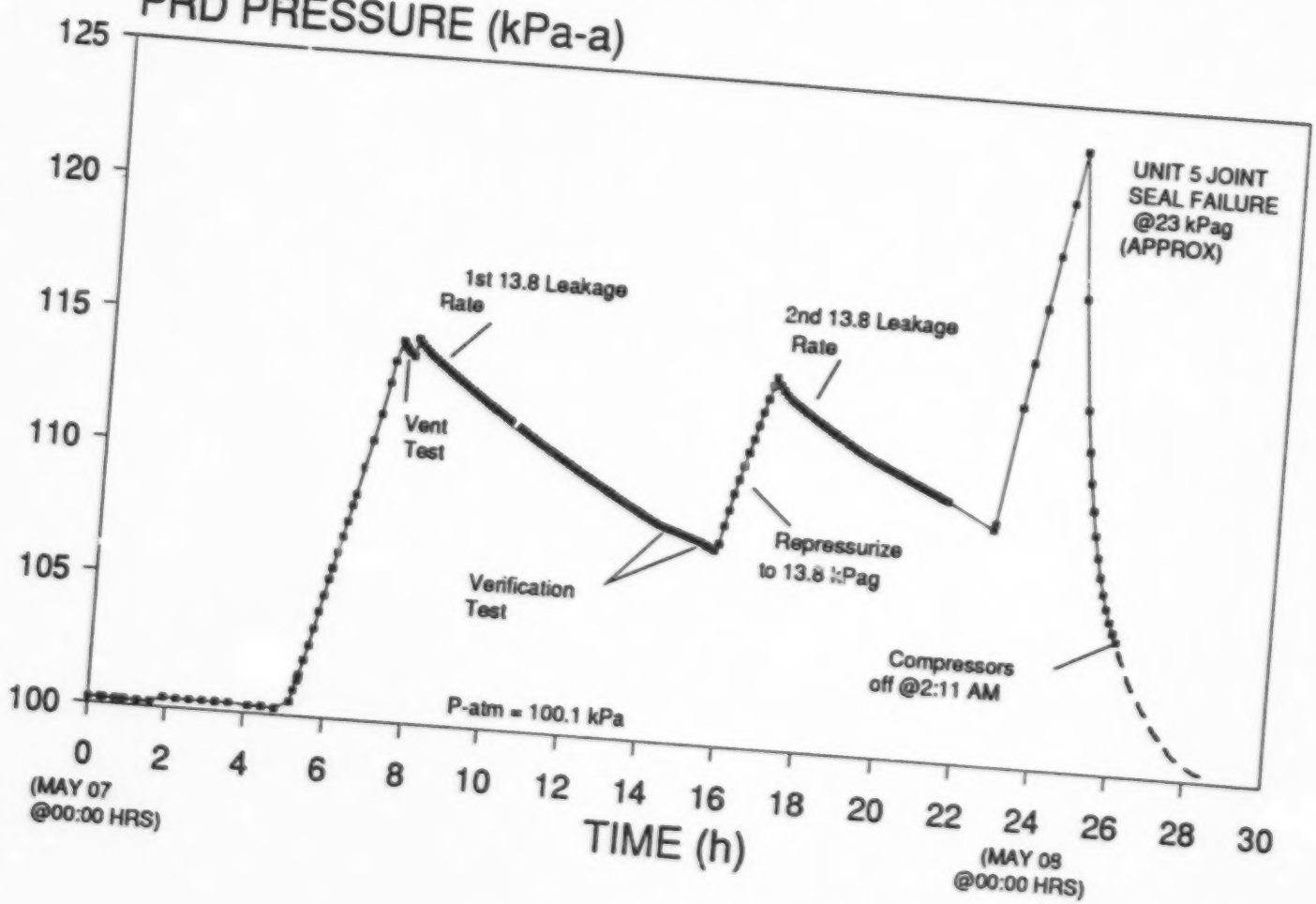

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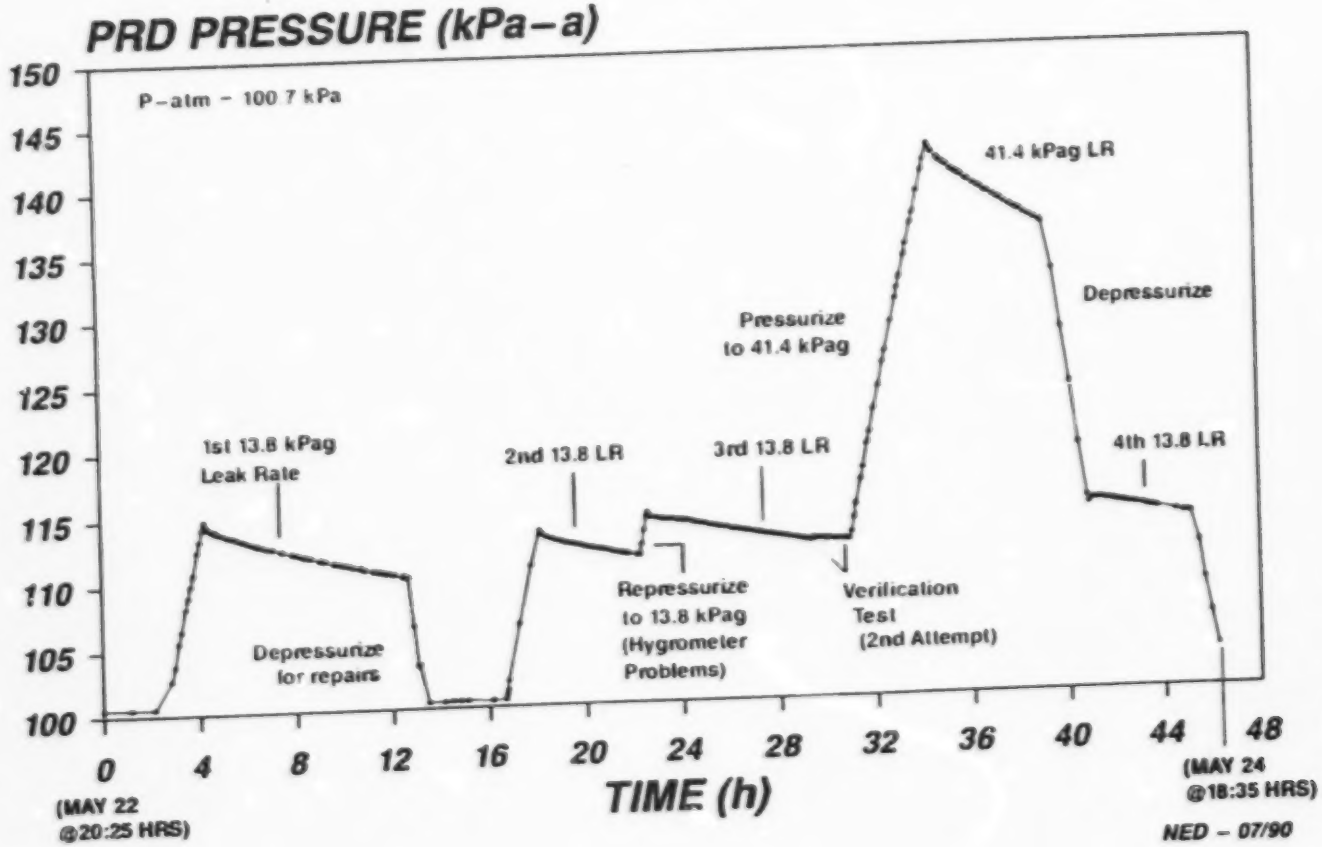
FIGURE 4

1990 PNGS 'AS-LEFT' PRD PRESSURE TEST
PRD PRESSURE vs TIME



tracer gas injection was postponed until a leakage rate measurement could be made. The initial result was >1% and a decision to repair was made. The PRD was depressurized on May 23, 1990 to allow caulking and manlifts to be put into the PRD. Once all the repair work was complete, the PRD was again pressurized to about 14 kPag starting at about 18:35 on May 23, 1990. The tracer gas was released at about 19:00, after the PRD was pressurized to 14 kPag. The tracer gas concentration in the PRD was estimated to be about 100 ppm. The tracer gas sampling at 14 kPag was begun at about 20:30 EDT. Pressurization to 41.4 kPag (6 psig) was begun about 03:15 on May 24, 1990 and tracer gas sampling was begun at about 08:00 EDT. The tracer gas concentration in the duct at 41.4 kPag was estimated to be about 85 ppm.

3.1 Leak Search for the "As Found" PRD Pressure Test

A total of 102 air samples were analyzed for tracer gas. All of the tracer gas leak search results obtained for the "As Found" pressure test are summarized in Table A2. The air samples were collected when the PRD was at a pressure of about 14 kPag. Tracer gas concentrations were measured downstream from the following isolation components:

- all but two of the PRD EJ seals
- Unit 2, 4 and 7 PRD-RB bulkheads
- PRV 1, 5, 6, 11 and 12 lower diaphragms and seals.

Tracer gas was not detected in the vacuum building basement. In the weather enclosure that protects the vacuum ducts (VD), some hissing was detected however the air samples taken in the vicinity had tracer gas concentrations that were below the detection limit.

Tracer gas can be used to test for leakage of the PRD EJ seals as there is a neoprene weather cover installed on the outside surface of the PRD at each EJ seal. Tracer gas sampling locations for a typical PRD EJ seal are shown in Figure 5.

The estimated volume in the interspace between a PRD EJ seal and the weather cover is about 18 m^3. The interspace is not well ventilated and can be assumed to be a reasonably stagnant volume. For example, a leak rate of 18 m^3/h (23 kg/h) through/around a PRD EJ seal would lead to near PRD duct concentration (100 ppm) in the interspace after 5 hours.

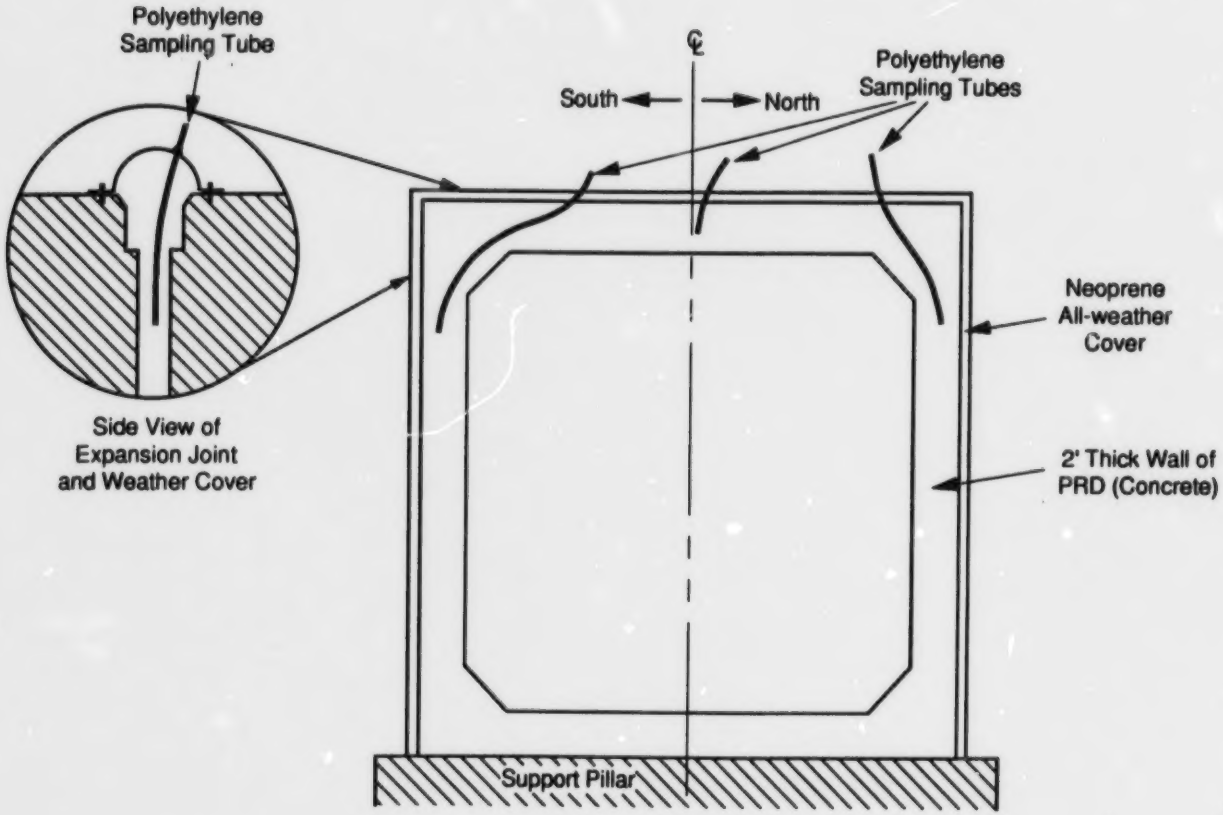


FIGURE 5

CROSS-SECTION OF THE PRD

All but two of the PRD EJ seals had tracer gas concentrations >10 ppm after 5 hours of exposure (>2.3 kg/h leak rate). PRD EJ seals 44, 48, 62, 66, and 71 were >45 ppm (>10 kg/h leak rate). The PRD tracer gas concentration was estimated to be approximately 100 ppm during the sampling period. The PRD EJ seals for PNGS 'A' were performing better than the PNGS 'B' joint seals after 5 hours at 14 kPag. The results are summarized in Table I.

Each PRV sits in a housing on top of a vacuum duct (VD) on the floor of the PRD. The housing and associated seals and diaphragms used with a PRV are shown as a sectional view in Figure 6. The inside diameter of each VD is 1.81 m and has an overall length ranging from 29.18 to 34.22 m. The estimated volume between the PRV and the vacuum building entrance ranges from 75.06 to 88.02 m^3 depending on the VD considered. The vacuum building end of each VD was open to atmosphere during each pressure test. The two tracer gas samples that were taken from each VD, one near the PRV (sample #1) and one near the bottom of the VD (sample #2), are shown in Figure 7. The distance between sampling points was estimated to be about 6.2 m. The air in each VD was assumed to be reasonably stagnant and can be treated as a fixed volume. The PNGS PRV and VD identification codes are shown in Figure 8.

The tracer gas concentration results for each PRV are given in Table II and provide a clear comparison of the relative integrity of the 12 PRV's. Tracer gas was detected downstream of PRV's 1, 5, 6, 11 and 12. For PRV's 5 and 11, the tracer gas concentrations measured were an order of magnitude greater than for the other three PRV's that leaked. Tracer gas was also detected at the lower sampling position on the VD for PRV's 5 and 11, confirming that ethylene tracer gas was indeed diffusing through/around the PRV's to the vacuum building opening in each VD (see Table A2-3).

The first tracer gas air sample for each VD was taken about 1 m below the PRV and was assumed to represent a 2.57 m^3 volume. For PRV 1, a tracer gas concentration of 7.0 ppm was measured after about three hours of exposure to 100 ppm ethylene in the PRD. The estimated leak rate as calculated from dilution ratios, to achieve this concentration, is 0.078 kg/h. This estimated leak rate is small compared to the overall leak rate of 356 kg/h measured for the PRD at 12.1 kPag during the "As Found" pressure test/8/. It can be assumed that the air leakage through/around the PRV diaphragms and seals into the VD contribute little to the overall leak rate measured for the PRD.

Each VD is attached to the floor of the PRD with an elastomeric expansion seal (see Figure 6). Tracer gas penetration through the floor seals was investigated with samples taken at the top of

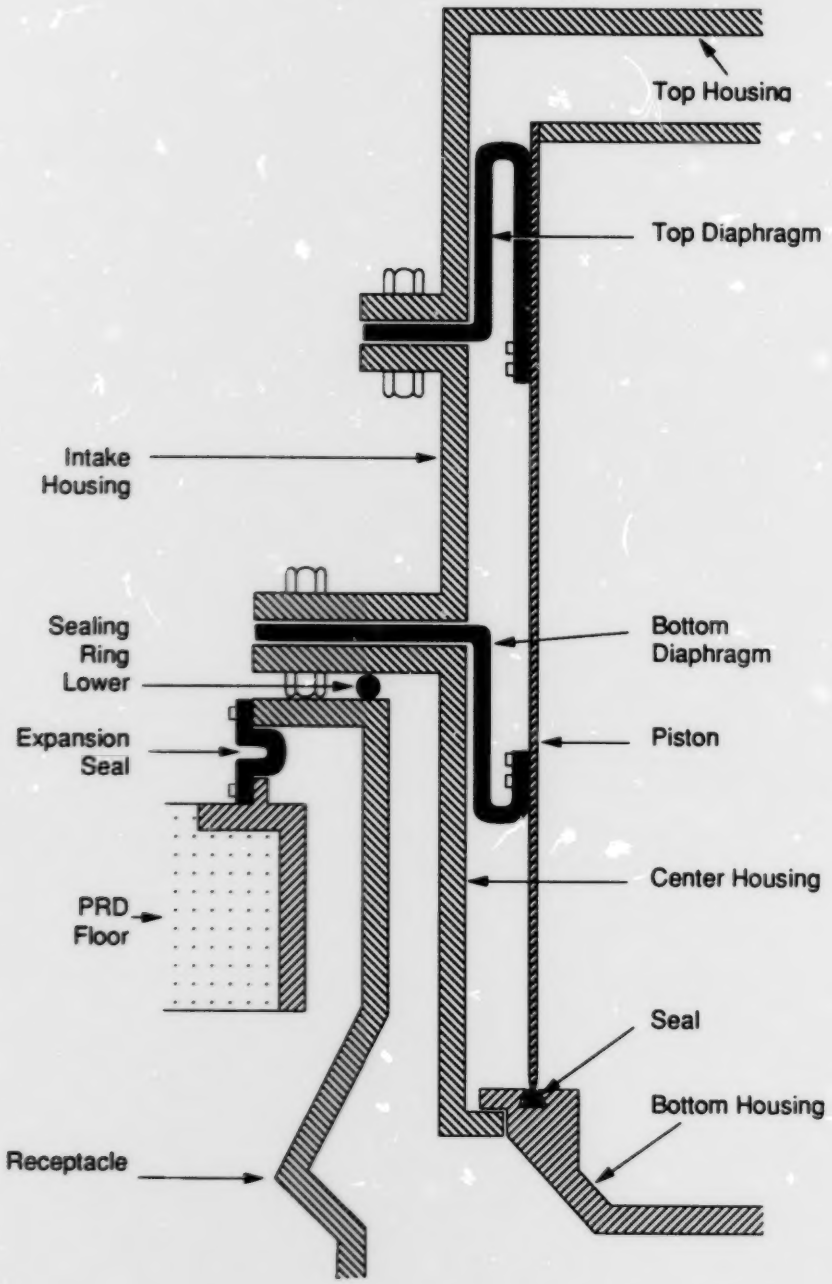


FIGURE 6

SEALS AND DIAPHRAGMS ASSOCIATED WITH A PRESSURE RELIEF VALVE

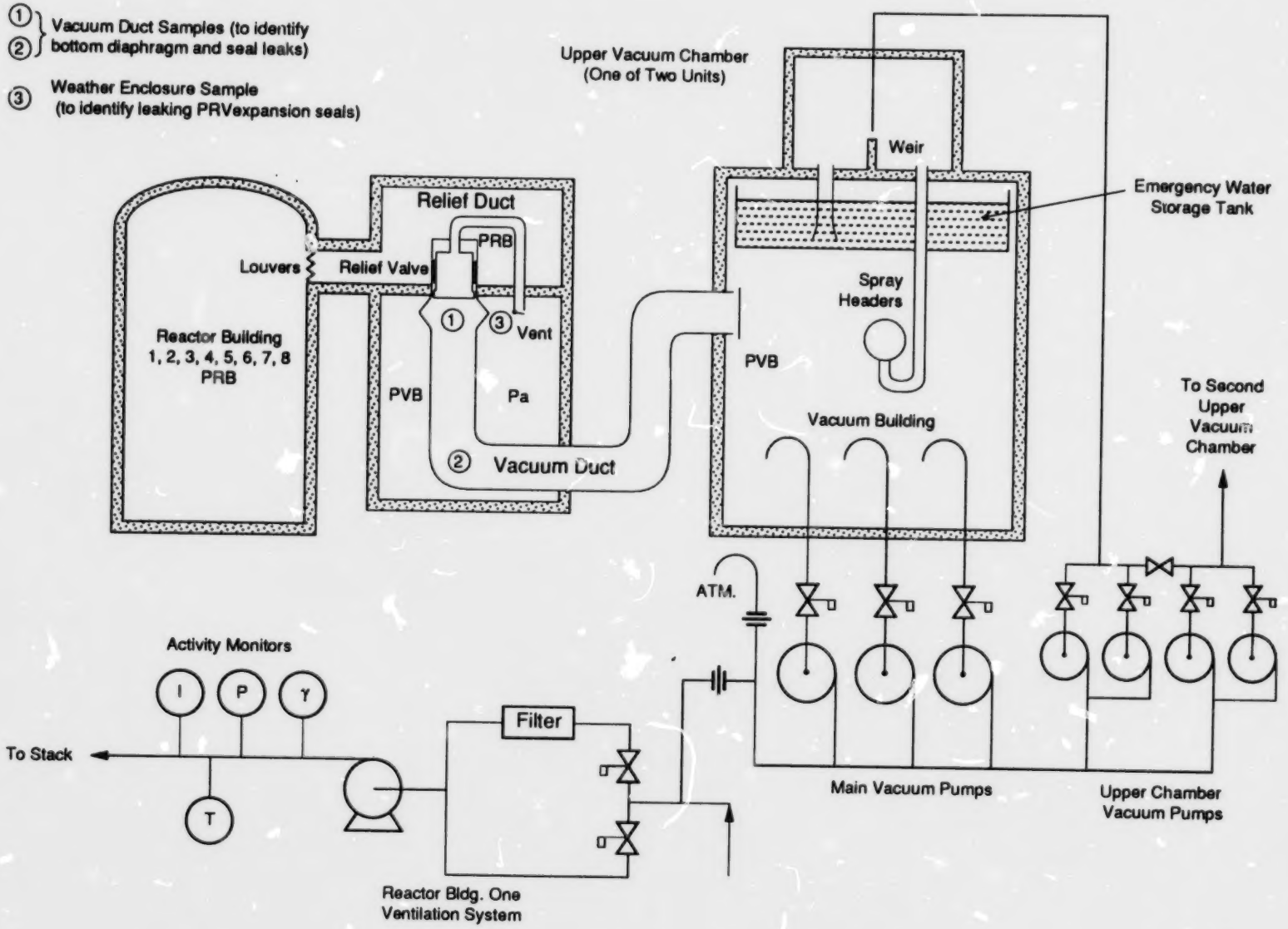


FIGURE 7

PICKERING NEGATIVE PRESSURE CONTAINMENT

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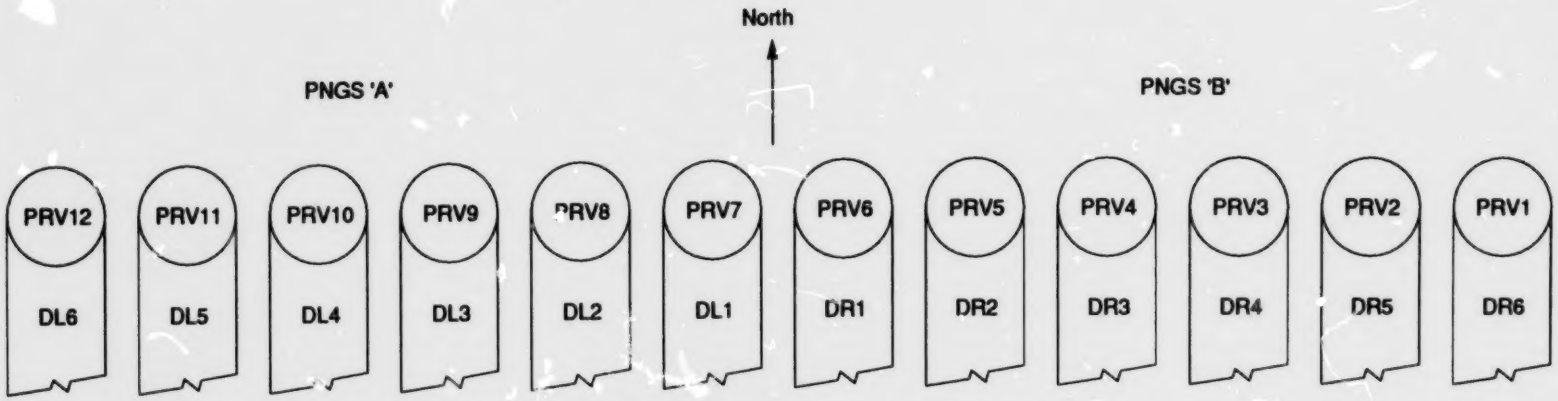

FIGURE 8

VACUUM DUCT AND PRESSURE RELIEF VALVE LABELING FOR PICKERING NGS

TABLE I

TRACER GAS RESULTS FOR PRD EXPANSION JOINT SEAL-WEATHER COVER INTERSPACE AIR SAMPLES TAKEN DURING "AS FOUND" AND "AS LEFT" PRESSURE TESTS

PRD Expansion Joint Seal Number	Ethylene Concentration (ppm) "As Found" PRD Pressure 14 kPag (Exposure Time 5h)	"As Left" PRD Pressure 41 kPag (Exposure Time 12 to 14h)
PRD-EJ 23	0.71	41.3
PRD-EJ 18	21.5	2.7
PRD-EJ 14	21.9	1.6
PRD-EJ 10	6.3	34.5
PRD-EJ 5	0.51	1.7
PRD-EJ 0	43.3	39.0
PRD-EJ 36	11.9	12.1
PRD-EJ 40	7.8	38.0
PRD-EJ 44	42.0	17.1
PRD-EJ 48	36.3	58.0
PRD-EJ 53	96.0	63.7
PRD-EJ 58	75.3	44.7
PRD-EJ 62	9.9	77.0
PRD-EJ 66	44.0	76.5
PRD-EJ 71	75.7	76.3

Note: The ethylene concentrations listed above are all averages of the three samples collected from each PRD-EJ seal interspace.

TABLE II

TRACER GAS RESULTS FOR AIR SAMPLES TAKEN IN VACUUM DUCTS DOWNSTREAM OF PRESSURE RELIEF VALVE LOWER DIAPHRAGMS AND SEALS DURING "AS FOUND" AND "AS LEFT" PRD PRESSURE TESTS

PRV Seal and Vacuum Duct Number	Ethylene Concentration (ppm) "As Found" PRD Pressure 14 kPag	"As Left" PRD Pressure 14 kPag	41 kPag
PRV1-DR6	7.0	<0.27	<0.27
PRV2-DR5	<0.10	<0.27	<0.27
PRV3-DR4	<0.10	<0.27	2.3
PRV4-DR3	<0.10	<0.27	<0.27
PRV5-DR2	6.2	<0.27	<0.27
PRV6-DR1	0.20	<0.27	0.65
PRV7-DL1	<0.10	<0.27	0.95
PRV8-DL2	<0.10	<0.27	<0.27
PRV9-DL3	<0.10	<0.27	<0.27
PRV10-DL4	<0.10	<0.27	<0.27
PRV11-DL5	2.2	<0.27	0.33
PRV12-DL6	0.23	3.5	4.8

Note: The ethylene concentrations listed above are all from samples collected in the vacuum duct near the PRV lower diaphragm and seal.

the weather enclosure which is the floor of the PRD (see sample #3 on Figure 7). The results are given in Table A2-3. Tracer gas was not detected in any of these samples.

Each of the Reactor Buildings (RB) at PNGS is estimated to have a contained air volume of approximately 51,000 m^3. The tracer gas concentration of 100 ppm ethylene in the PRD at a pressure of about 14 kPag was selected so that an air leakage rate of at least 5 kg/h could be estimated/detected by tracer gas measurements in each RB boiler room. For the "As Found" pressure test three boiler room samples were taken for each RB, one near the PRD-RB bulkhead and two general area samples. The tracer gas results are given in Table A2-2 and summarized in Table III. The PRD-RB bulkheads for Units 2, 4 and 7 showed measurable leakage after 5 hours. The leakage into Unit 4 was at least an order of magnitude greater than for the other two leaking Unit bulkheads.

An estimate of the contribution of the leakage through Unit 2 PRD-RB bulkhead to the overall PRD leak rate prior to repairs is attempted. From Table III and Table A2-2, the average ethylene tracer gas concentration in Unit 2 boiler room was 2.0 ppm after about 11 hours of inleakage of 100 ppm ethylene from the PRD. The estimated inleakage rate is 94 kg/h at NTP if the entire containment volume is considered and 73 kg/h if only the boiler room volume (31,000 m^3) is considered. The leakage through the PRD-RB bulkheads can be considered to be significant contributors to the overall leak rate measured for the PRD. Based on the leak search results crews were dispatched to inspect the leaking RB bulkheads.

The entire tracer gas leak search was to be repeated at about 41 kPag, however, during pressurization to 41 kPag PRD expansion joint seal #44 (see Figure 1) just west of Unit 5 ruptured at approximately 23 kPag, leaving a 230 ± 15 cm^2 hole/8/. The pressure test was abandoned at this point.

From the tracer gas results discussed above, the relative leakage contribution order from the seals and isolations can be inferred for the "As Found" pressure test. The relative order for leakage contribution is as follows:

each PRV	<<	PRD EJ seal	<	PRD-RB Bulkhead isolation.
(0.2 kg/h)		(up to 18 kg/h)		(up to 100 kg/h)

The PRV and PRD-RB bulkhead leakage is inter-containment whereas the PRD EJ seal leakage is containment outleakage to the local environment.

TABLE III

TRACER GAS RESULTS FOR REACTOR BUILDING AIR SAMPLES TAKEN DURING "AS FOUND" AND "AS LEFT" PRESSURE TESTS

Reactor Building Number	Ethylene Concentration (ppm) "As Found" PRD Pressure 14 kPag	"As Left" PRD Pressure 41 kPag
RB1	<0.10	<0.27
RB2	0.39	0.55
RB3	<0.10	<0.27
RB4	1.35 (2.0)	<0.27
RB5	<0.10	<0.27
RB6	<0.10	<0.27
RB7	0.19	<0.27
RB8	<0.10	<0.27

Note: The ethylene concentrations listed above are averages of at least three samples collected in the respective Unit boiler rooms.

The value in brackets is the average of two area samples.

3.2 Leak Search for the "As Left" Pressure Test

For the "As Left" PRD pressure test, a change in the test boundary was made. The Filtered Air Discharge System (FADS) was removed from the test boundary for the "As Left" test. The implication of this change is that the contribution from the FADS to the "As Found" leakage cannot be quantified.

A total of 148 air samples collected during the "As Left" PRD pressure test, were analyzed for tracer gas. The results are summarized in Tables A3 to A3-3. The air samples were collected at PRD pressures of about 14 and 41 kPag at the locations described in Table A1.

Significant tracer gas concentrations were detected near the following isolation locations:

- all but three of the PRD EJ seals,
- Unit 2 PRD-RB bulkhead, and
- PRV 12 at 14 kPag and PRV's 3, 6, 7, 11 and 12 at 41 kPag.

Tracer gas was not detected in the upper part of the weather enclosure near the VD to PRV expansion seals nor in the vacuum building basement.

Tracer gas samples of the PRD EJ seal/weather cover interspace were unavailable at 14kPag as access to the top of the PRD was not allowed at night. The PRD EJ interspace tracer gas samples were obtained at a PRD pressure of about 41 kPag, some 12 to 14 hours after the introduction of the tracer gas. The results are given in Table I. All of the PRD EJ seal to metal mounting component interfaces leaked to some degree. Three of the EJ seals (5, 14 and 18) performed very well after 12 hours of exposure to about 100 ppm ethylene, showing less than 3 ppm in the interspace. The PNGS 'B' EJ interspaces were found to contain higher concentrations of tracer gas than the PNGS 'A' interspaces, similar to the results obtained for the "As Found" leak search. The direct comparison of old and new PRD EJ seal performance is not possible, however, the similarity in the PNGS 'A' and 'B' EJ seal leakage results for both pressure tests suggests that the seating of the EJ seals be considered as a source for leaks.

Each VD below the PRV housing was sampled at 14 and 41 kPag. The results are presented in Table A3-3 and Table II. At 14 kPag after

exposure to the ethylene in the PRD for about 2 hours, only PRV 12 diaphragm and/or seal was found to be leaking. After 3.5 hours of exposure, PRV's 3, 6 and 12 were found to be leaking. After 14 hours of exposure plus an increase in the PRD pressure to 41 kPag, PRV's 3, 6, 7, 11 and 12 were found to be leaking. The PRV's 3 and 12 showed the most leakage into their respective VDs. Tracer gas was not detected in the areas near the PRD floor to VD expansion seals located in the upper portion of the weather enclosure that protects the VD's.

The Reactor Building (RB) boiler room tracer gas samples were taken about 2 to 3 hours after the release of the tracer gas into the PRD. Five air samples were taken in each Unit boiler room, one near the PRD-RB bulkhead and four distributed evenly over the boiler room area. The results are presented in Table A3-2 and Table III. Tracer gas was detected only in Unit 2 boiler room near the PRD-RB bulkhead. The remaining samples were all below detection indicating little penetration through the other bulkheads.

Tracer gas samples were not obtained for the Reactor Buildings at a PRD pressure of 41 kPag as the leakage rate measured by NED personnel was 0.95% per hour/8/, below the Ontario Hydro operation target of 1% per hour. It was deemed unnecessary to incur additional radiation dose to obtain the RB samples for the sake of completeness.

Direct comparisons of the tracer gas concentration results for the "As Found" and "As Left" PRD pressure tests are made in Tables I to III. An improvement in the PRD-RB bulkhead leakage and in the PRV seals at 14 kPag is noted. The PRD EJ interspace continued to show the presence of tracer gas even after seal replacement. The PNGS 'B' interspaces appeared to have more tracer gas inleakage than the PNGS 'A' interspaces during both pressure tests.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions result directly from the work performed:

- the tracer gas technique performed very well in identifying leaks from areas such as the PRD-RB bulkheads, the PRV diaphragms and seals and the PRD EJ seals, but it should be noted that the technique provided only a qualitative estimate of leakage,

- tracer gas was detected in the majority of the PRD EJ interspaces even after replacement of all the seals, however, due to rapid saturation of the interspace by small leaks it is not possible to say whether the leakage detected from around the seal to the metal mounting component interfaces was significant,

- five PRV's were found to be leaking during each pressure test. PRV's 6, 11 and 12 continued to show some leakage even after diaphragm and seal replacement,

- the expansion seals used to attach each VD receptacle to the PRD floor did not show any detectable leakage during either pressure test, and

- the PNGS 'A' Unit 2 PRD-RB bulkhead leaked during both pressure tests.

It is recommended that RB entries to obtain boiler room tracer gas samples be incorporated directly into future outage work plans. This would improve the sample/analysis turn around time needed to evaluate the integrity of the PRD-RB bulkheads.

It is also recommended that more definitive start times be established for future pressure tests to facilitate assembly of all leak search personnel required to perform the work. The twenty-four hour nature of the operation at PNGS necessitates that for any future outages additional leak search staff be approved to allow shift crews to be formed in order to reduce fatigue.

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APPENDIX A

TABLE A1

AIR SAMPLING LOCATIONS USED FOR TRACER GAS LEAK SEARCH DURING THE "AS FOUND" AND "AS LEFT" PRD PRESSURE TESTS

1) Fifteen Pressure Relief Duct (PRD) Expansion Joint (EJ) seal - Weather Cover Interspaces for Joints 23, 18, 14, 10, 5, 0, 36, 40, 44, 48 53, 62, 66 and 71 were sampled. Three samples were taken per interspace as shown in Figure 5. The relative positions of the expansion joints along the PRD are shown in Figure 1.

2) The air space in the vacuum duct (VD) below the twelve Pressure Relief Valve (PRV) lower diaphragms and seals that isolate the PRD volume from the twelve vacuum ducts that connect the PRD to the Vacuum Building (VB) was sampled. Two samples per VD, one close to the lower PRV diaphragm and the other near the bottom of the vacuum duct are shown in Figure 7. The labelling scheme used for the vacuum ducts and PRVs is shown in Figure 8.

3) Eight PRD - Reactor Building (RB) bulkheads that isolate the PRD from each RB containment were sampled. A minimum of three samples were taken in each RB, one near the bulkhead which is located in the PRD wall and at least two other area samples in the unit boiler room which is isolated from the PRD by the bulkhead. The location of each RB relative to the PRD is shown in Figure 1.

4) Twelve PRV expansion seals that attach the vacuum duct (valve receptacle) to the floor of the PRD were sampled. The samples were taken between each pair of vacuum ducts at the top of the weather enclosure used to protect the vacuum ducts.

5) Any other areas near penetrations into the PRD where tracer gas samples may be helpful in pinpointing leaks.

TABLE A2

TRACER GAS RESULTS FOR PICKERING NGS
"AS FOUND" PRD PRESSURE TEST - May 7, 1990

Label Format: Test No - Location - Seal Type - Sample No

LEGEND:
PRD - Pressure Relief Duct NS - North Side
TS - Top Side
SS - South Side
PRV - Pressure Relief Valve
RB# - Reactor Building No.
EJ - Expansion Joint
VD - Vacuum Duct Number + T = Top or B = Bottom
VB - Vacuum Building

PICKERING NGS 'A' Expansion Joint Seals

Sample Code	Ethylene Concentration (ppm) (PRD pressure = 14 kPag)	Time
1-PRD-EJ-23NS	0.85	na
1-PRD-EJ-23TS	0.79	na
1-PRD-EJ-23SS	0.51	na
1-PRD-EJ-18NS	14.5	na
1-PRD-EJ-18TS	19.5	na
1-PRD-EJ-18SS	30.5	na
1-PRD-EJ-14NS	20.5	na
1-PRD-EJ-14TS	17.8	na
1-PRD-EJ-14SS	27.5	na
1-PRD-EJ-10NS	na	na
1-PRD-EJ-10TS	10.0	na
1-PRD-EJ-10SS	2.6	na
1-PRD-EJ-5NS	0.36	na
1-PRD-EJ-5TS	0.34	na
1-PRD-EJ-5SS	0.83	na
1-PRD-EJ-0NS	41.0	na
1-PRD-EJ-0TS	46.0	na
1-PRD-EJ-0SS	43.0	na

TABLE A2-1

PICKERING NGS 'B' Expansion Joint Seals

Sample Code	Ethylene Concentration (ppm) (PRD pressure = 14 kPag)	Time
1-PRD-EJ-36NS	9.4	na
1-PRD-EJ-36TS	11.8	12:00
1-PRD-EJ-36SS	14.5	na
1-PRD-EJ-40NS	na	na
1-PRD-EJ-40TS	10.0	12:00
1-PRD-EJ-40SS	5.5	na
1-PRD-EJ-44NS	26.0	na
1-PRD-EJ-44TS	50.0	12:00
1-PRD-EJ-44SS	50.0	na
1-PRD-EJ-48NS	100.0	na
1-PRD-EJ-48TS	90.0	12:00
1-PRD-EJ-48SS	98.0	na
1-PRD-EJ-53NS	71.0	na
1-PRD-EJ-53TS	80.0	12:00
1-PRD-EJ-53SS	75.0	na
1-PRD-EJ-58NS	9.8	na
1-PRD-EJ-58TS	9.1	12:00
1-PRD-EJ-58SS	10.8	na
1-PRD-EJ-62NS	32.0	na
1-PRD-EJ-62TS	50.0	12:00
1-PRD-EJ-62SS	50.0	na
1-PRD-EJ-66NS	37.0	na
1-PRD-EJ-66TS	36.0	12:00
1-PRD-EJ-66SS	36.0	na
1-PRD-EJ-71NS	75.0	na
1-PRD-EJ-71TS	75.0	12:00
1-PRD-EJ-71SS	77.0	na

TABLE A2-2

PRESSURE RELIEF DUCT SAMPLES

Sample Code	Ethylene Concentration (ppm) (PRD pressure = 14 kPag)	Time
1-PRD-1	70.0	na
1-PRD-2	71.0	11:00
1-PRD-3	69.0	na

REACTOR BUILDING SAMPLES

Sample Code		Ethylene Concentration (ppm) (PRD pressure = 14 kPag)	Time
1-RB1-1		<0.10	12:00
1-RB1-2		<0.10	12:00
1-RB1-3		<0.10	12:00
1-RB2-1		0.39	12:20
1-RB2-2		0.37	12:20
1-RB2-3		0.40	12:20
1-RB3-1		<0.10	11:45
1-RB3-2		0.21	11:45
1-RB3-3		0.10	11:45
1-RB4-1		na	10:45
1-RB4-2		3.6	10:45
1-RB4-3		1.35	10.45
1-RB4-5	Repeat Samples	52.0	17:00
1-RB4-6		2.0	17:00
1-RB4-7		2.1	17:00
1-RB4-8		2.1	17:00
1-RB5-1		0.12	10:20
1-RB5-2		<0.10	10:20
1-RB5-3		<0.10	10:20
1-RB6-1		<0.10	11:00
1-RB6-2		<0.10	11:00
1-RB6-3		<0.10	11:00
1-RB7-1		0.28	11:30
1-RB7-2		0.15	11:30
1-RB7-3		<0.10	11:30
1-RB8-1		<0.10	12:10
1-RB8-2		<0.10	12:10
1-RB8-3		<0.10	12:10

TABLE A2-3

PRESSURE RELIEF VALVE SAMPLES

Sample Code	Ethylene Concentration (ppm) (PRD pressure = 14 kPag)	Time
1-PRV1-DR6T	7.0	na
1-PRV1-DR6B	0.55	na
1-PRV2-DR5T	<0.10	na
1-PRV2-DR5B	<0.10	na
1-PRV3-DR4T	<0.10	na
1-PRV3-DR4B	<0.10	na
1-PRV4-DR3T	<0.10	na
1-PRV4-DR3B	na	na
1-PRV5-DR2T	6.2	na
1-PRV5-DR2B	0.70	na
1-PRV6-DR1T	0.20	na
1-PRV6-DR1B	<0.10	na
1-PRV7-DL1T	<0.10	09:04
1-PRV7-DL1B	<0.10	09:04
1-PRV8-DL2T	<0.10	09:11
1-PRV8-DL2B	<0.10	09:11
1-PRV9-DL3T	<0.10	09:18
1-PRV9-DL3B	<0.10	09:18
1-PRV10-DL4T	<0.10	09:25
1-PRV10-DL4B	<0.10	09:25
1-PRV11-DL5T	2.2	09:31
1-PRV11-DL5B	<0.10	09:31
1-PRV12-DL6T	0.23	09:38
1-PRV12-DL6B	<0.10	09:38
1-PRV11&12-DL5&DL6	<0.10	na
1-PRV8&9-DL2&DL3	<0.10	na
1-PRV5&6-DR1&DR2	<0.10	09:57
1-PRV2&3-DR4&DR5	<0.10	09:57
OTHER TRACER GAS SAMPLES AROUND THE PRD AND RB's		
1-VB-BASEMENT-1	<0.10	na
1-VB-BASEMENT-2	<0.10	na

TABLE A3

TRACER GAS RESULTS FOR PICKERING NGS
"AS LEFT" PRD PRESSURE TEST - May 22/23, 1990

Label Format: Test No - Location - Seal Type - Sample No

LEGEND: PRD - Pressure Relief Duct NS - North Side
TS - Top Side
SS - South Side

PRV - Pressure Relief Valve
RB# - Reactor Building No.
EJ - Expansion Joint
VD - Vacuum Duct Number + T = Top or B = Bottom
VB - Vacuum Building

PICKERING NGS 'A' Expansion Joint Seals

Sample Code	Date: May 22, 1990 PRD =14 kPag Ethylene (ppm)	Time	Date: May 23, 1990 PRD = 41 kPag Ethylene (ppm)	Time
2-PRD-EJ-23NS	-	-	40.0	10:57
2-PRD-EJ-23TS	-	-	42.5	10:02
2-PRD-EJ-23SS	-	-	na	-
2-PRD-EJ-18NS	-	-	7.6	10:17
2-PRD-EJ-18TS	-	-	0.29	10:23
2-PRD-EJ-18SS	-	-	0.29	10:29
2-PRD-EJ-14NS	-	-	na	-
2-PRD-EJ-14TS	-	-	0.27	10:38
2-PRD-EJ-14SS	-	-	2.9	10:45
2-PRD-EJ-10NS	-	-	33.0	09:29
2-PRD-EJ-10TS	-	-	na	-
2-PRD-EJ-10SS	-	-	36.0	09:35
2-PRD-EJ-5NS	-	-	1.1	09:19
2-PRD-EJ-5TS	-	-	1.0	09:19
2-PRD-EJ-5SS	-	-	2.9	09:24
2-PRD-EJ-0NS	-	-	na	-
2-PRD-EJ-0TS	-	-	38.0	09:16
2-PRD-EJ-0SS	-	-	40.0	09:12

TABLE A3-1

PICKERING NGS 'B' Expansion Joint Seals

Sample Code	Date: May 22, 1990 PRD =14 kPag Ethylene (ppm)	Time	Date: May 23, 1990 PRD = 41 kPag Ethylene (ppm)	Time
2-PRD-EJ-36NS	-	-	15.0	10:28
2-PRD-EJ-36TS	-	-	12.3	10:35
2-PRD-EJ-36SS	-	-	9.0	10:40
2-PRD-EJ-40NS	-	-	39.0	10:05
2-PRD-EJ-40TS	-	-	38.5	10:10
2-PRD-EJ-40SS	-	-	36.5	10:16
2-PRD-EJ-44NS	-	-	27.5	09:52
2-PRD-EJ-44TS	-	-	19.5	09:57
2-PRD-EJ-44SS	-	-	4.3	09:54
2-PRD-EJ-48NS	-	-	57.0	10:38
2-PRD-EJ-48TS	-	-	60.0	10:44
2-PRD-EJ-48SS	-	-	57.0	10:51
2-PRD-EJ-53NS	-	-	66.0	09:52
2-PRD-EJ-53TS	-	-	67.0	10:00
2-PRD-EJ-53SS	-	-	58.0	10:05
2-PRD-EJ-58NS	-	-	47.0	10:15
2-PRD-EJ-58TS	-	-	34.0	10:21
2-PRD-EJ-58SS	-	-	53.0	10:27
2-PRD-EJ-62NS	-	-	78.0	09:30
2-PRD-EJ-62TS	-	-	78.0	09:35
2-PRD-EJ-62SS	-	-	75.0	09:35
2-PRD-EJ-66NS	-	-	77.0	09:17
2-PRD-EJ-66TS	-	-	76.0	09:20
2-PRD-EJ-66SS	-	-	na	-
2-PRD-EJ-71NS	-	-	72.0	09:02
2-PRD-EJ-71TS	-	-	80.0	09:07
2-PRD-EJ-71SS	-	-	77.0	09:47

TABLE A3-2

REACTOR BUILDING SAMPLES

Sample Code	PRD =14 kPag		PRD = 41 kPag	
	Ethylene (ppm)	Time	Ethylene (ppm)	Time
2-RB1-1	<0.27	09:10	-	-
2-RB1-2	<0.27	09:10	-	-
2-RB1-3	<0.27	09:10	-	-
2-RB1-4	<0.27	09:10	-	-
2-RB1-5	<0.27	09:10	-	-
2-RB2-1	0.55	09:45	-	-
2-RB2-2	<0.27	09:45	-	-
2-RB2-3	<0.27	09:45	-	-
2-RB2-4	<0.27	09:45	-	-
2-RB2-5	<0.27	09:45	-	-
2-RB3-1	<0.27	10:10	-	-
2-RB3-2	<0.27	10:10	-	-
2-RB3-3	<0.27	10:10	-	-
2-RB3-4	<0.27	10:10	-	-
2-RB3-5	<0.27	10:10	-	-
2-RB4-1	<0.27	10:30	-	-
2-RB4-2	<0.27	10:30	-	-
2-RB4-3	<0.27	10:30	-	-
2-RB4-4	<0.27	10:30	-	-
2-RB4-5	<0.27	10:30	-	-
2-RB5-1	<0.27	10:40	-	-
2-RB5-2	<0.27	10:40	-	-
2-RB5-3	<0.27	10:40	-	-
2-RB5-4	<0.27	10:40	-	-
2-RB5-5	<0.27	10:40	-	-
2-RB6-1	<0.27	10:25	-	-
2-RB6-2	<0.27	10:25	-	-
2-RB6-3	<0.27	10:25	-	-
2-RB6-4	<0.27	10:25	-	-
2-RB6-5	<0.27	10:25	-	-
2-RB7-1	<0.27	09:35	-	-
2-RB7-2	<0.27	09:35	-	-
2-RB7-3	<0.27	09:35	-	-
2-RB7-4	<0.27	09:35	-	-
2-RB7-5	<0.27	09:35	-	-
2-RB8-1	<0.27	10:05	-	-
2-RB8-2	<0.27	10:05	-	-
2-RB8-3	<0.27	10:05	-	-
2-RB8-4	<0.27	10:05	-	-
2-RB8-5	<0.27	10:05	-	-

TABLE A3-3

PRESSURE RELIEF VALVE SAMPLES

Sample Code	PRD =14 kPag			PRD = 41 kPag	
	Ethylene (ppm) first	second	Time 1st/2nd	Ethylene (ppm)	Time
2-PRV1-DR6T	<0.27	<0.27	08:55/	<0.27	-
2-PRV1-DR6B	<0.27	-	08:55/na	-	-
2-PRV2-DR5T	<0.27	<0.27	09:07/	<0.27	-
2-PRV2-DR5B	<0.27	-	09:07/na	-	-
2-PRV3-DR4T	0.27	0.75	09:09/	2.3	-
2-PRV3-DR4B	<0.27	-	09:09/na	-	-
2-PRV4-DR3T	<0.27	<0.27	09:11/	<0.27	-
2-PRV4-DR3B	<0.27	-	09:11/na	-	-
2-PRV5-DR2T	<0.27	<0.27	09:15/	<0.27	-
2-PRV5-DR2B	<0.27	-	09:15/na	-	-
2-PRV6-DR1T	<0.27	0.30	09:17/	0.65	-
2-PRV6-DR1B	<0.27	-	09:17/na	-	-
2-PRV7-DL1T	<0.27	<0.27	09:20/	0.95	-
2-PRV7-DL1B	<0.27	-	09:20/na	-	-
2-PRV8-DL2T	<0.27	<0.27	09:23/	<0.27	-
2-PRV8-DL2B	<0.27	-	09:23/na	-	-
2-PRV9-DL3T	<0.27	<0.27	09:25/	<0.27	-
2-PRV9-DL3B	<0.27	-	09:25/na	-	-
2-PRV10-DL4T	<0.27	<0.27	09:30/	<0.27	-
2-PRV10-DL4B	<0.27	-	09:30/na	-	-
2-PRV11-DL5T	<0.27	<0.27	09:33/	0.33	-
2-PRV11-DL5B	<0.27	-	09:33/na	-	-
2-PRV12-DL6T	3.5	3.6	09:36/	4.8	-
2-PRV12-DL6B	<0.27	-	09:36/na	-	-
2-PRV-DL11&12	<0.27	<0.27	08:40/10:30	<0.27	10:55
2-PRV-DL8&9	<0.27	<0.27	08:40/10:30	<0.27	10:55
2-PRV-DL7&8	<0.27	<0.27	08:40/10:30	<0.27	10:55
2-PRV-DL5&6	<0.27	<0.27	08:40/10:30	<0.27	10:55
2-PRV-DL4&5	<0.27	<0.27	08:40/10:30	<0.27	10:55
2-PRV-DL2&3	<0.27	<0.27	08:40/10:30	<0.27	10:55

TABLE A3-4

PRESSURE RELIEF DUCT SAMPLES

Sample Code	Ethylene Concentration (ppm) (PRD pressure = 14 kPag)	Time
2-PRD-1	na	na
2-PRD-2	na	na
2-PRD-3	na	na
OTHER TRACER GAS SAMPLES AROUND THE PRD AND RB's		
2-VB-BASEMENT-1	<0.27	10:46
2-VB-BASEMENT-2	<0.27	10:56